This document contains the Comprehensive Conservation and Management Plan for Narragansett Bay, December 1992: Background: State of the Bay sections: Pollutant Sources, Status and Trends, Living Resources and Critical Habitats, Public Health Concerns, Bay and Watershed Governance, and Priorities

The report (narragansett_ccmp_pt3.pdf) can be downloaded from:

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learn about new sewage treatment methods. Conversion of the Field's Point facility to use an activated-sludge process was completed in 1934. Other improvements to the system were made in subsequent years.

By the 1970s, this system was again inadequate. The facility had become antiquated, an inadequately sized staff maintained it, and charges of political mismanagement were leveled at its directors. Raw sewage was regularly released into the Bay, and sewage solids were found on beaches. In 1980, a regional approach to managing the problems of sewage waste treatment was adopted with the creation of the Narragansett Bay Commission (NBC). With financial assistance from the EPA and the State of Rhode Island, the NBC has been able to reconstruct and upgrade the Field's Point facility.

The Bay also receives numerous discharges from the industries that flourish in the region. Today, 33 major industries in Massachusetts and Rhode Island continue to discharge directly into the watershed under federal National Pollutant Discharge Elimination System (NPDES) major permits or Rhode Island Pollutant Discharge Elimination System (RIPDES) permits. There are also numerous industrial and commercial discharges to sewer systems. These indirect discharges ultimately reach Narragansett Bay.

Sewage effluent and sludge are not the only materials that have been disposed of in Narragansett Bay. Because many parts of Narragansett Bay are shallow, regular dredging of channels and harbors has been conducted to maintain access for the small boats or large ships that use them. Materials dredged from the bottom were disposed of on salt marshes and other coastal lands until the 1960s. Many of Narragansett Bay's fringing salt marshes were filled to support coastal development.

Dredged material was also disposed in Narragansett Bay's deeper waters. Between 1949 and 1966, material was dumped off the southern end of Prudence Island, as well as at the Brenton Reef Disposal Area, near the mouth of Narragansett Bay in Rhode Island Sound. Dredged material is no longer disposed within Narragansett Bay waters because no site has been designated in the Bay. Upland disposal still occurs, subject to receipt of permits from the Rhode Island Coastal Resources Management Council (CRMC), the Rhode Island Department of Environmental Management (RIDEM), and the U.S. Army Corps of Engineers (USACOE).

02-03 Pollutant Sources, Status, and Trends

02-03-01 Pollutant Sources and Water Quality

Three major classes of anthropogenic pollutants are discharged to Narragansett Bay and the Bay basin: fecal wastes, potentially including pathogenic bacteria and viruses; excess nutrients and oxygen-demanding organic matter; and toxic pollutants, including trace metals and organic compounds. Although these pollutants are generated by industrial, commercial and domestic activities throughout the Bay basin, they enter the Bay from myriad point and nonpoint sources.

Point sources, such as the discharge pipes for WWTFs and industrial facilities, are a major route for delivery of pollutants to the Bay. Each year approximately 98 billion gallons of treated wastewater enter the Bay from 33 WWTFs serving over one million people in Rhode Island and Massachusetts. In addition, each year over 100 CSOs in the basin discharge approximately four billion gallons of untreated sewage and stormwater to the Bay waters (Figure 715-02(7)). Direct industrial discharges also contribute to the pollutant load.

Nonpoint sources are more diffuse and difficult to quantify. Nonpoint sources of contaminants to the Bay include runoff from highways, parking lots, farmlands and lawns. Seepage from on-site sewage disposal systems; discharges by ships and boats; accidental chemical spills; and resuspension of contaminated sediments also represent locally important sources of contaminated deposition.

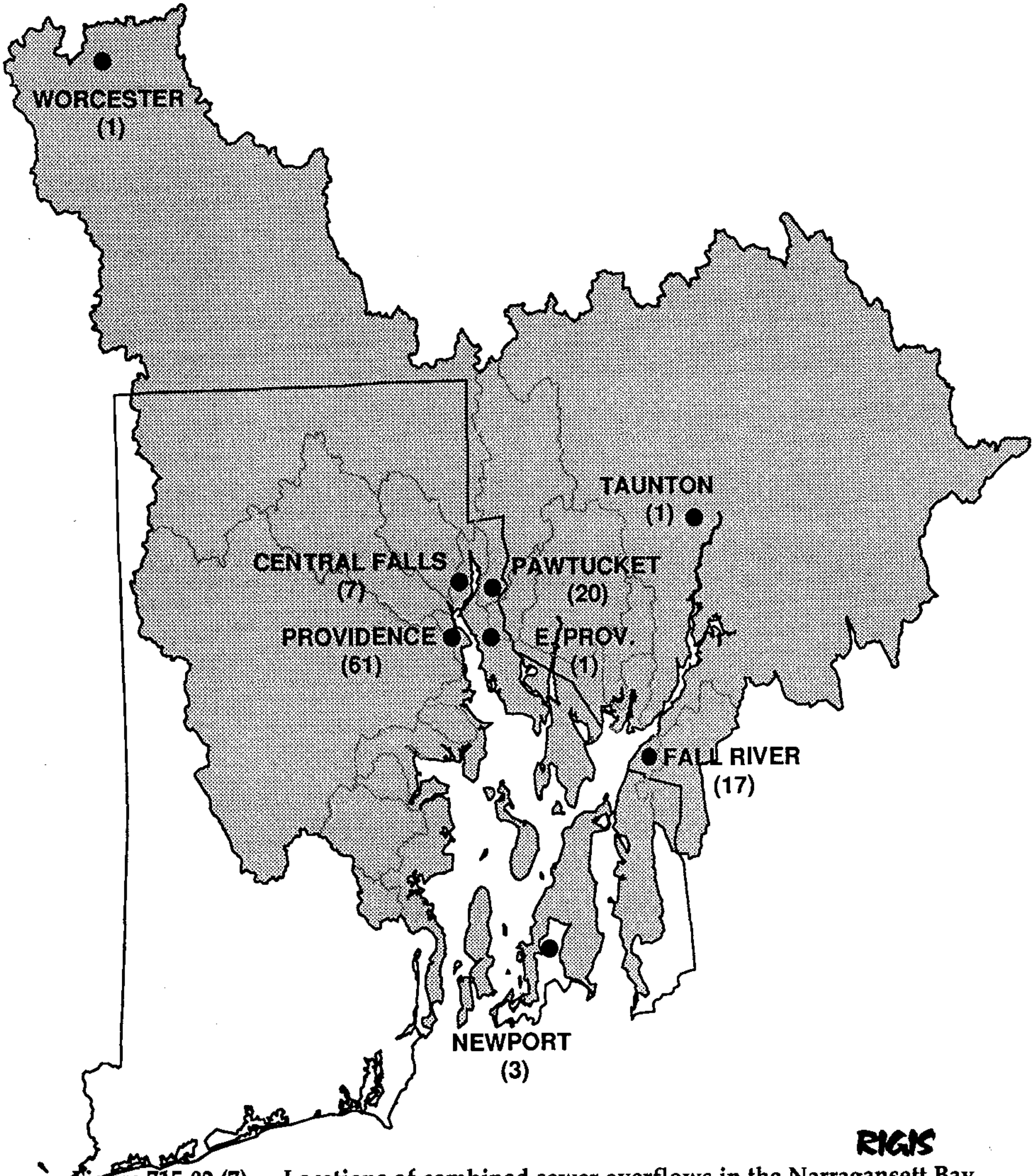


Figure 715-02 (7). Locations of combined sewer overflows in the Narragansett Bay watershed. (Map provided by NBP, RIGIS.)

The states of Rhode Island and Massachusetts classify the state's waters according to the condition and goals for the waters' uses. Seawaters are classified as follows:

Class SA	Suitable for bathing and contact recreation, shellfish harvesting for direct human consumption, and fish and wildlife habitat.
Class SB	Suitable for bathing and contact recreation, for shellfish harvesting for human consumption after depuration, and fish and wildlife habitat.
Class SC	Suitable for boating and secondary contact recreation, fish and wildlife habitat, industrial cooling, and aesthetic value.

Discharges into the waters must meet limitations necessary to ensure compliance with specific state water quality standards, which limit concentrations of specific pollutants in order to protect aquatic life and human health. The CRMC has established different water use classifications for Rhode Island's coastal waters in order to govern authorized uses of coastal waters. The CRMC's six water use categories are:

Type 1	Conservation area
Type 2	Low-intensity use
Type 3	High-intensity boating
Type 4	Multipurpose waters
Type 5	Commercial and recreational harbors
Type 6	Industrial waterfronts and commercial navigation channels.

02-03-02 Suspended Solids and Biochemical Oxygen Demand (BOD)

Rivers constitute the major erosional source of suspended solids. However, suspended solids and oxygen-demanding substances also enter the Bay from point and nonpoint source discharges to the rivers. Coastal wastewater treatment facilities are another major source of solids and BOD. CSOs and industrial discharges also contribute to BOD loadings.

Historically, BOD loadings have increased as a result of population growth. However, these loadings decreased throughout the basin with the implementation of secondary treatment of municipal wastes as required under the federal Clean Water Act. Secondary treatment employs biological methods to reduce the amount of organic material in wastewater. The trend toward improved oxygen concentrations in the Providence River can be correlated with improved BOD and suspended solids removal by the Blackstone Valley District Commission (BVDC) [Note that the BVDC WWTF is now the NBC Bucklin Point WWTF.] and the NBC Field's Point.

02-03-03 Pathogens

Pathogens are disease-causing organisms such as bacteria, viruses, and protozoa. Human pathogens, including the bacteria responsible for cholera and typhoid, and viruses responsible for infectious hepatitis and gastroenteritis can be present in human fecal wastes and may enter the Bay from WWTFs, CSOs, septic systems, and, in some areas, discharges from boats. Water-borne pathogens can be hazardous to swimmers and to people who eat raw or incompletely cooked seafood harvested from sewage-contaminated waters.

Rhode Island and Massachusetts open and close beaches and shellfish-growing areas based upon concentrations of one type of bacteria, fecal coliforms. These bacteria are considered "indicators," that is, while they are not pathogenic, they indicate the presence of fecal waste and the possible presence of pathogenic bacteria. Another type of bacteria, enterococcus, has been proposed by EPA as a better indicator for marine swimming beaches, and the NBP has funded research on the potential use of alternative indicators of human fecal waste, such as the use of a male-specific bacteriophage and the spores of the bacterium *Clostridium perfringens*. Because the bacteriophage and *Clostridium perfringens* spores are more resistant to chlorination from wastewater treatment than other indicators, they may be more accurate environmental indicators of the presence of human fecal waste.

Fecal wastes and potential pathogens enter the Bay from WWTFs, bypasses to those facilities, CSOs, stormdrains, septic systems, stormwater runoff, and, in some areas, boater discharges. Although the dry weather loadings of fecal coliform bacteria are so large that more than 28 percent of Narragansett Bay is permanently closed to shellfishing, CSOs represents the greatest inputs of coliform bacteria to the Providence River and Mount Hope Bay during rainstorms. In rainy weather, WWTF bypasses and the CSOs in Providence, Pawtucket, and Central Falls are the major sources of untreated or partially treated sewage to the Providence-Seekonk River and the Upper Bay. Similarly CSOs in Fall River, MA, are the major source of untreated fecal waste to Mount Hope Bay. During rainstorms, sampling has shown that 95 percent of the fecal coliform bacteria entering Mount Hope Bay and 80 percent entering the Providence River come from CSOs. Annual loadings of coliform bacteria from CSOs are about 10,000 times higher than the loadings from wastewater treatment facilities and about 200 times higher than loadings from separated stormdrains.

Nonurban, developing coastal areas are also affected by discharges and releases of fecal wastes to coastal waters. Areas presumptively affected by boater wastes because of dense assemblages of marinas and mooring fields are seasonally closed to shellfishing. Improperly sited, poorly designed, inadequately maintained, and failing septic systems, and illegal sanitary cross connections to stormdrains also contribute fecal wastes to coastal waters and have resulted in local restrictions on shellfish harvesting.

02-03-04 Nutrients

Nutrients are essential to the functioning of the Narragansett Bay ecosystem. However, excessive inputs of nutrients, especially nitrogen and phosphorus can cause ecological problems and impairments to uses of portions of the Bay. Nutrients can stimulate blooms of microscopic plants, called phytoplankton. When these phytoplankton die, they decay. The bacteria causing the decay consume oxygen in the water, potentially leaving insufficient oxygen for shellfish, fish, and other animals. Blooms of larger macroalgae (seaweeds) can carpet coves and other enclosed areas. In extreme conditions, oxygen depletion related to nutrient loadings can kill fish and invertebrates and produce anoxic sediment conditions.

Nutrients enter the Bay from WWTFs, CSOs, individual septic systems, runoff from agricultural land and lawns, groundwater and the atmosphere (Figure 715-02(8)). The EPA and the National Oceanic and Atmospheric Administration (NOAA) have classified Narragansett Bay as receiving average amounts of nutrients compared to other estuaries in the northeast. However, the effects of excess nutrients are more important in coves and poorly flushed areas than in the open areas of the Bay. Unfortunately, few data are available for the small coves.

The lowest concentrations of dissolved oxygen in the Bay are found in the Providence, Seekonk, Pawtuxet, and Blackstone Rivers during the late summer (Pilson and Hunt, 1989; Penniman *et al.*, 1991b). Nitrates and phosphates are most concentrated in these areas and in the Taunton River because of major urban wastewater inputs of sewage (Figure 715-02(9)). However, pictures taken with a sediment-profiling camera have indicated that the aquatic communities living in portions of Greenwich Bay and Potowomut Cove are also stressed, perhaps as a result of excessive nutrient loads from point and nonpoint sources (Valente *et al.*, 1992).

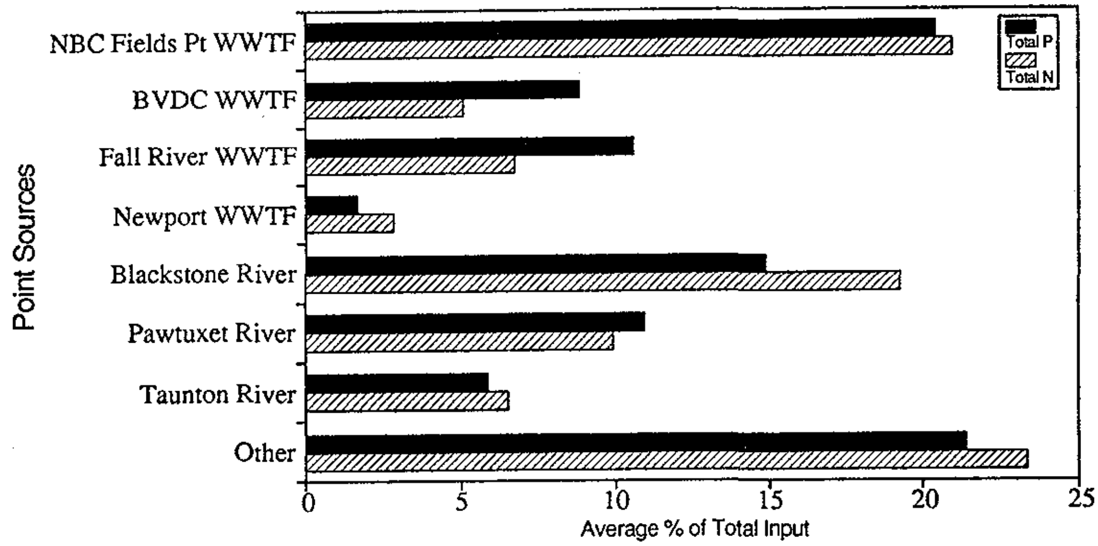


Figure 715-02 (8). **Point sources of nutrients to Narragansett Bay. (Data are from Pilson and Hunt, 1989. "Other" refers to other drainage areas.) [Note that the BVDC WWTF is now the NBC Bucklin Point WWTF.]**

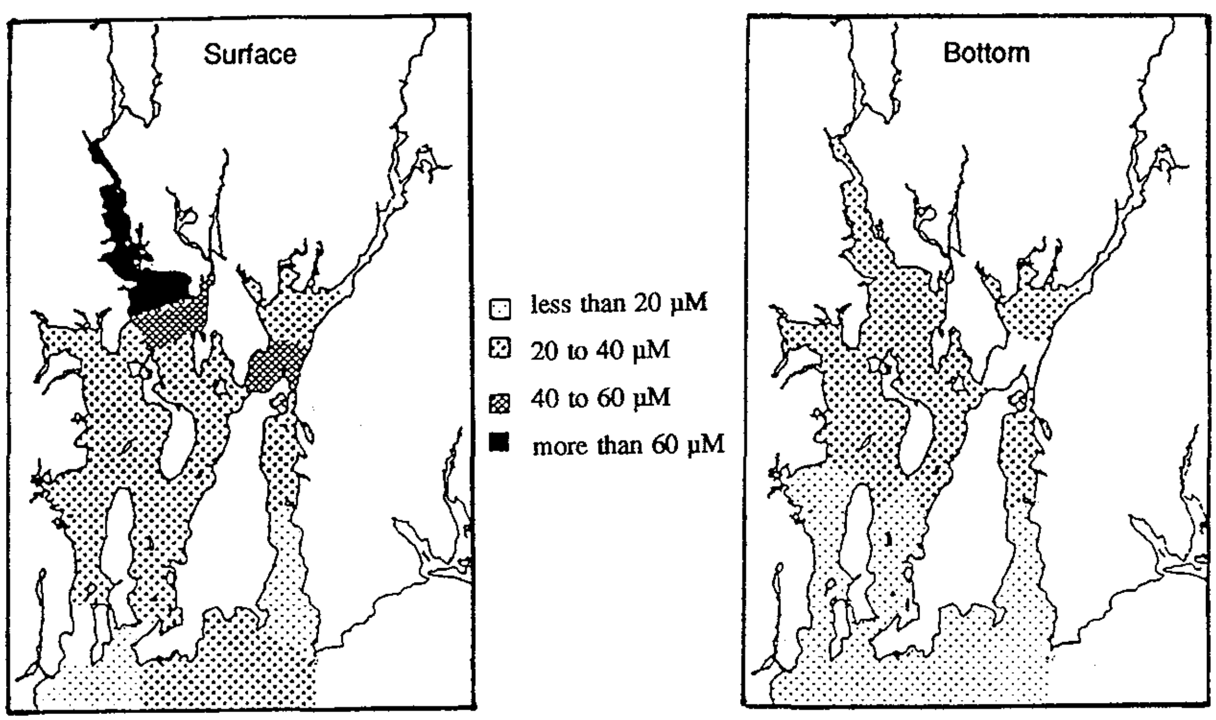


Figure 715-02 (9). **Nitrogen concentrations for surface and bottom waters in October 1985. (Data are from Pilson and Hunt, 1989.)**

02-03-05 Toxic Pollutants

Narragansett Bay has a long history of inputs of toxic metals and toxic organic compounds (Figure 715-02(10)). Many toxic metals and some toxic organic compounds exist naturally in low concentrations. Some toxic metals are often called trace metals, because they occur naturally in low concentrations and are essential nutrients for plants and animals. At higher concentrations, however, toxic metals and organic compounds can cause reproductive or metabolic disorders and death, and additionally may accumulate in the tissues of plants and animals. These metals and organic compounds are most toxic to sea life when they are dissolved in water. Metals that are adsorbed to sediment particles and buried in oxygen-poor sediments are relatively nontoxic unless the sediments are resuspended, re-aerated, and solubilized or consumed by organisms. However, many petroleum-based and synthetic organic compounds remain toxic when they are adsorbed to particles.

Toxic metals of particular concern in the environment include copper, cadmium, lead, zinc, chromium, silver, nickel, and mercury (Figure 715-02(11)). The largest anthropogenic sources of these metals originate in the most industrialized portion of the Bay watershed, where they are used in the manufacture of jewelry and other metal products, and the electroplating, cement, and textile industries. Copper also comes from copper water pipes used throughout the region in residential as well as commercial and industrial areas. The lead from solder used, until recently, to connect copper pipes can also leach into the water. In parts of the watershed where drinking water comes from reservoirs rather than groundwater, acid rain has caused the water to corrode the copper pipes and lead solder at a greater rate than normal. A major source of lead to the environment was from gasoline combustion until 1974, when unleaded fuel was required for all new automobiles. Burning of wood, coal, and oil has also contributed to increased environmental concentrations of metals.

During dry weather, most trace metals enter the Bay from the NBC Field's Point WWTF and upstream sources on the Blackstone River including the UBWPAD WWTF. During rainy weather, the major point sources are the NBC's Field's Point and NBC's Bucklin Point (formerly BVDC) WWTFs although the Blackstone and Pawtuxet rivers represent the largest metals loadings (Wright *et al.*, 1992a).

Concentrations of toxic metals are greatest in waters at the head of the Bay and decrease down-Bay toward Rhode Island Sound (Figure 715-02(12)). The highest concentrations of metals in the Upper Bay are found in the Seekonk River, where the Blackstone River enters the Bay (Bender *et al.*, 1989; Metcalf & Eddy, Inc., 1991a). Concentrations of dissolved nickel are 20 times higher in the Upper Bay than in Rhode Island Sound. Concentrations of cadmium are ten times higher, and concentrations of chromium are four times higher. Concentrations of copper and nickel are highest near the Field's Point WWTF and in the Blackstone River.

Toxic organic compounds include petroleum-derived contaminants known as petroleum hydrocarbons (PHCs) and polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides such as DDT. Petroleum compounds have many uses, such as for fuel or lubrication. PAHs are produced when wood, coal, or oil are burned. PCBs were widely used in electrical transformers until the domestic manufacture of PCBs was banned in 1977. DDT and some other persistent pesticides have also been banned from sale or use in the U.S. Today's pesticides generally degrade much faster than those used in the past. However, PCBs and DDT remain measurable in the Narragansett Bay ecosystem.

Petroleum compounds enter the Bay from large, catastrophic oil spills such as the *World Prodigy* spill which released 294,000 gallons of oil near the mouth of the Bay in June 1989. Although the amount of unrecovered oil from the *World Prodigy* was approximately equal to the amount of oil that enters

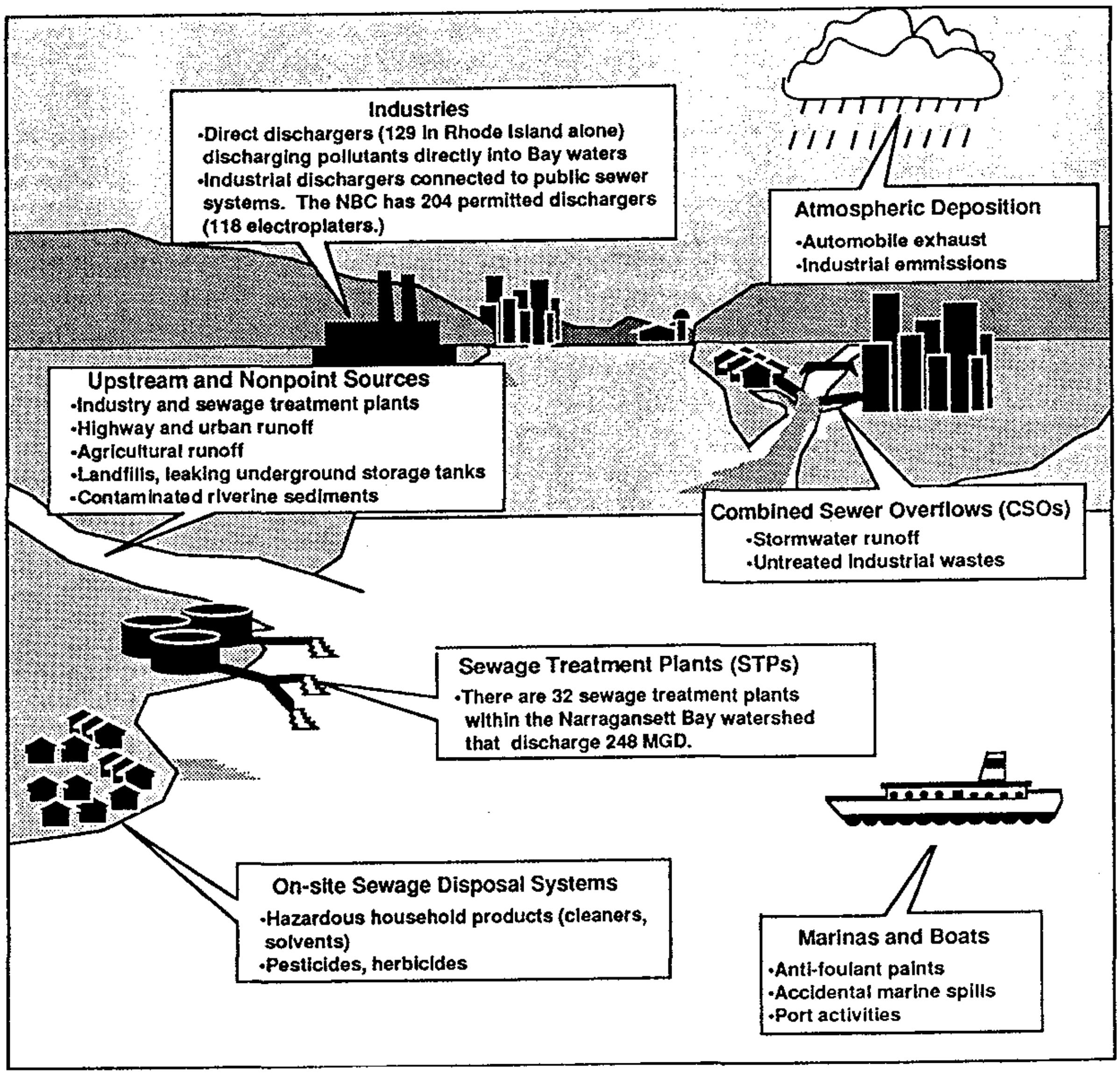


Figure 715-02 (10). Point and nonpoint sources of toxic contaminants to Narragansett Bay. (From NBP.)

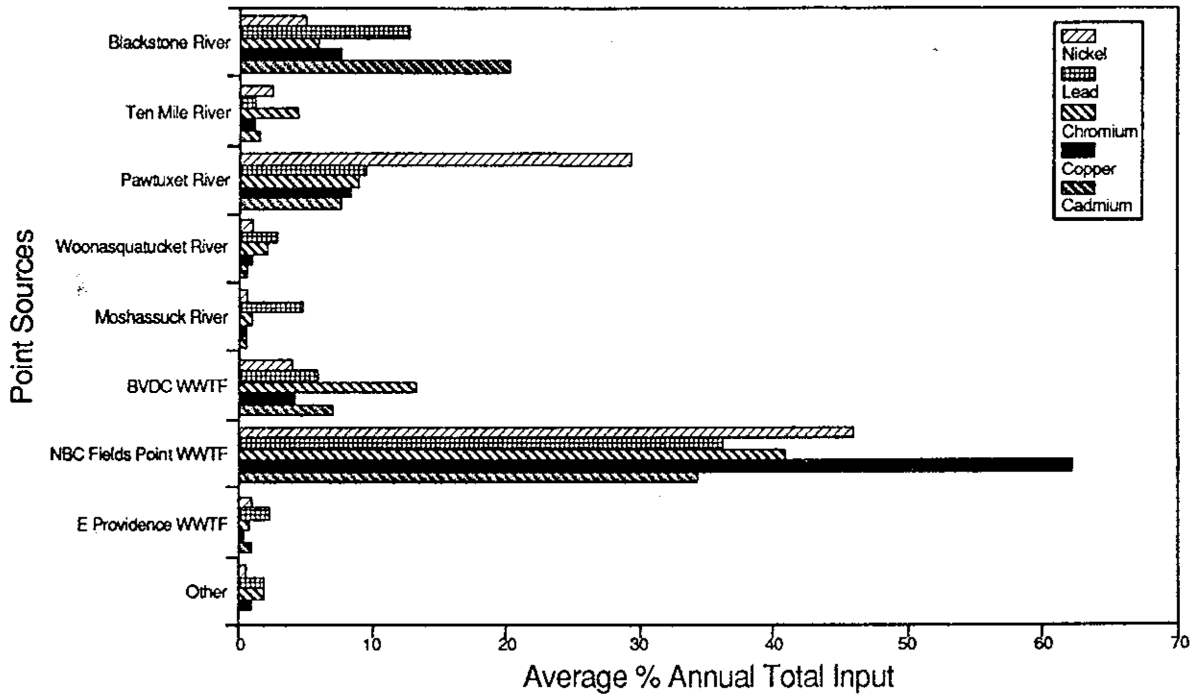


Figure 715-02 (11). Point sources of metals to Narragansett Bay. (Data from Metcalf & Eddy, Inc., 1991; "Other" includes BVDC CSO, BVDC Bypass, NBC CSO Area A.) [Note that BVDC is now part of NBC, and that the BVDC WWTF is now the NBC Bucklin Point WWTF.]

the Bay from all sources every two years, large, accidental spills represent only two percent of the annual average amount of oil entering Narragansett Bay. Therefore, persistent, chronic sources of petroleum to the Bay are of even greater importance. WWTFs and urban runoff are the largest contributors of these toxic organic compounds to the Bay. More than 60 percent of PHCs enter the Bay annually from WWTFs, primarily Field's Point. River inputs, mostly from the Taunton and Blackstone Rivers, account for more than 90 percent of PAHs (Metcalf & Eddy, Inc., 1991a).

Rivers also continue to contribute PCBs to the Bay, presumably from historic sources of contamination (Figure 715-02(13)). Water quality criteria for toxic pollutants, established to protect aquatic life, are exceeded in several locations within the Bay watershed primarily in the Blackstone, Pawtuxet, and Providence-Seekonk River basins (Table 715-02(2)) (Metcalf & Eddy, Inc., 1991a; Penniman *et al.*, 1991a).

02-03-06 Historical Trends and Current Status of Pollution in the Bay

The pollution history of urban estuaries such as Narragansett Bay can be told from undisturbed sediments (Corbin, 1989). Unless sediments have been disturbed by dredging, burrowing animals, or storms, the history of an area is shown in the layers of materials that are deposited on the sediment surface. The approximate age of sediments and sedimentation rates can be obtained using measurements of certain radioactive compounds.

Studies of Narragansett Bay's sediments have detected toxic metal pollution from the beginning of industrialization of the Providence area in 1750. Typical of most Narragansett Bay sediments, the sediments of the Seekonk River indicate sharp increases in

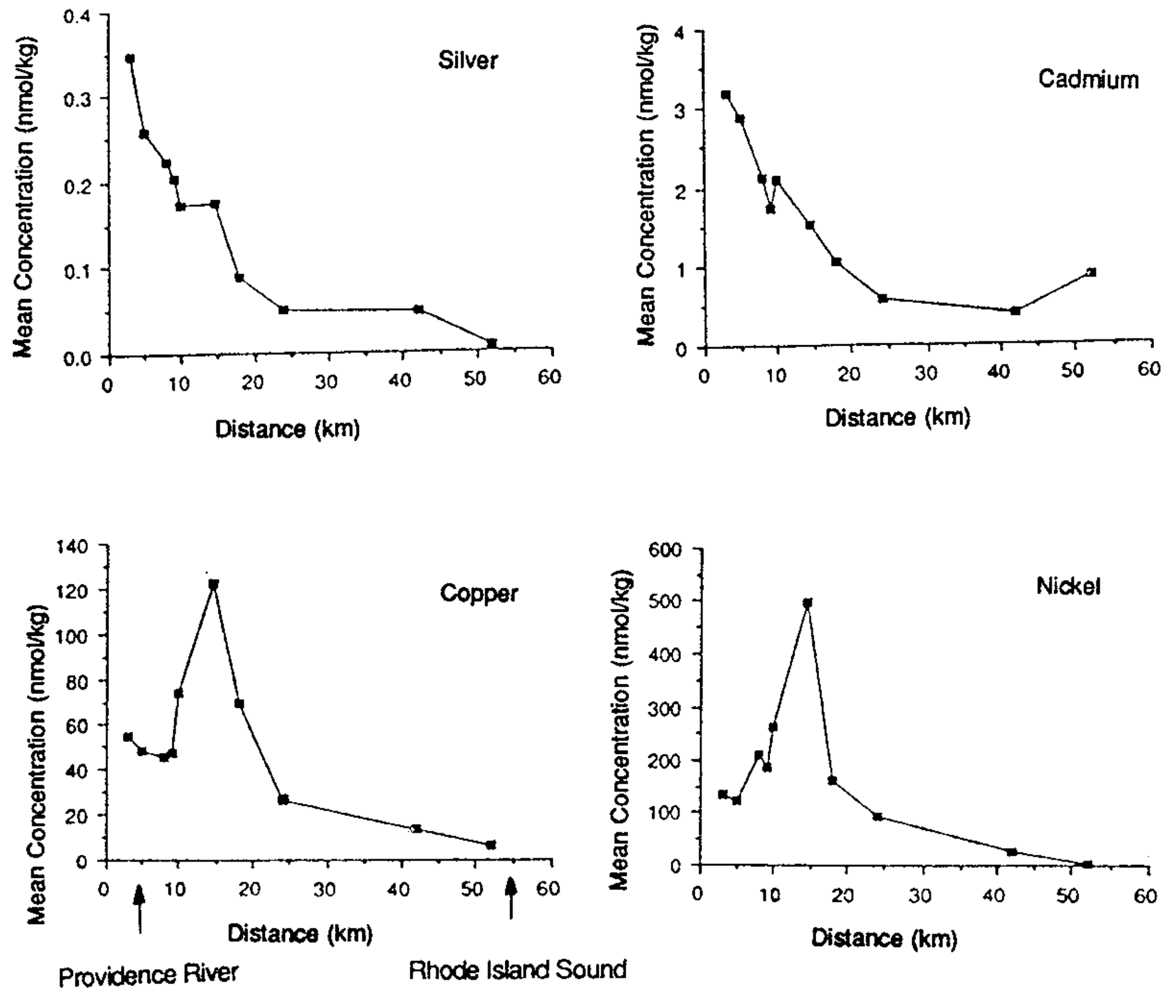


Figure 715-02 (12). Average concentrations (nanomoles/kg) of metals in Narragansett Bay as a function of distance (kilometers) from the Seekonk River. (Data are from Bender *et al.*, 1989, and are corrected for salinity effects.)

copper, lead, and silver loadings beginning in the 1860s, when metals use and processing increased dramatically, and ending abruptly in the late 1890s to 1900, around the time that the sewer system began discharging at Field's Point. The sediment cores indicate that metals inputs increased during the 1920s and 1930s (Figure 715-02(14)) (Corbin, 1989).

Concentrations of metals in the surface sediments show similar geographic trends to those in the water, with highest concentrations at the head of the Bay. However, there are also localized "hot spots," areas with especially high concentrations of contaminants not near centers of human activity. Such areas include Apponaug Cove, Brushneck Cove, Bullock's Cove, Greenwich Cove, Newport Harbor, Pawtuxet Cove, Warwick Cove, and Wickford Cove. Some of these sites reflect contamination from historic shipbuilding or industrial activity. A major "hot spot" is near Quonset Point where the Naval Air Rework Facility refurbished airplanes. Impoundments along the Blackstone River are the sites of some of the highest concentrations of metals ever measured in riverine sediments. Other sites, such as Bristol Harbor and Greenwich Cove, also receive toxic pollutants from residential, commercial, industrial, and agricultural activities.

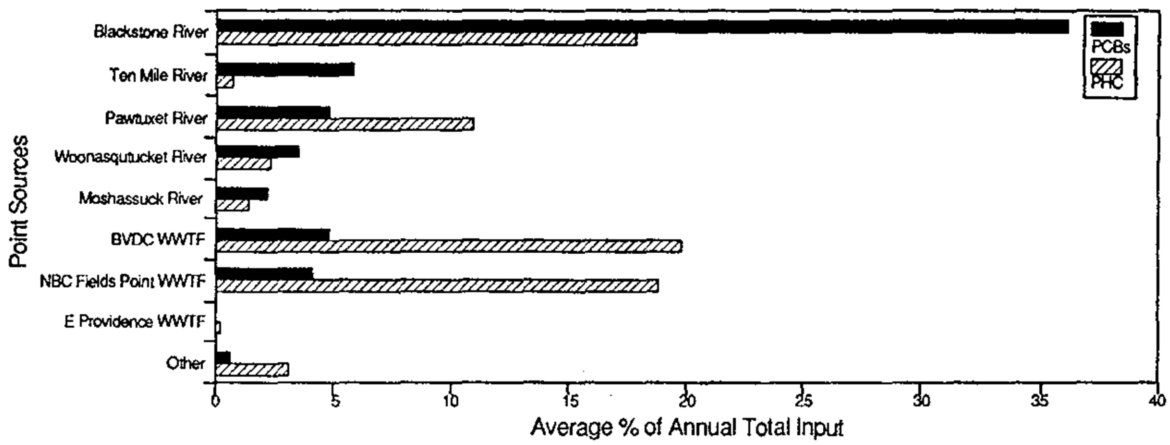


Figure 715-02 (13). Point sources of toxic organic contaminants to Narragansett Bay. (Data from Metcalf & Eddy, Inc., 1991a; "Other" includes BVDC CSO, BVDC Bypass, NBC CSO Area A.) [Note that BVDC is now part of NBC, and that the BVDC WWTF is now the NBC Bucklin Point WWTF.]

The deposition of organic pollutants has a different history from that of toxic metals. Concentrations of PHCs and PAHs both increase at points that coincide with increases in the use of fossil fuels in the late 1800s. At that time, coal and oil were burned in factories, and coal-fired passenger steamers cruised into the Bay. One sediment core from the East Passage has its highest concentrations of PHCs below the surface, possibly due to the disposal of dredged material that took place east of Prudence Island until 1965 (Corbin, 1989).

Some data show that inputs of some pollutants, notably PCBs and toxic metals, have decreased (Metcalf & Eddy, Inc., 1991a). For example, annual records from the Field's Point WWTF indicate that toxic metal inputs to the Bay decreased by 83 percent, from almost 1 million pounds to less than 200,000 pounds between 1981 and 1990 (Figure 715-02(15)). While recent trends show a decrease in concentrations of toxic metals, other evidence points to the need for continued monitoring and improvement. Data from the Providence River indicate that water quality standards for copper and nickel are exceeded. Concentrations of cadmium, copper, chromium, lead, and PCBs also exceed federal water quality criteria on many stretches of the Blackstone, Pawtuxet, Woonsocket, Moshassuck, and Ten Mile rivers (Table 715-02(2)).

Comparisons of studies conducted during 1977-1980 and 1985-1986 also show decreases in the concentrations of toxic metals found in sediments. There has been a fourfold decrease in copper concentrations in the surface sediments of the Providence River, and sediment nickel concentrations have decreased by 50 percent. In samples taken from Providence River sediments, there is no indication that inputs of cadmium or silver and, for some sites, lead have decreased (Corbin, 1989). However, sediment samples from the Seekonk River indicate a 71 percent decrease in lead since the 1950s (Corbin, 1989).

Recent declines in toxic metals loadings may be due in part to the industrial pretreatment programs implemented by 13 of Rhode Island's 19 WWTFs since 1982. Other reasons for the decline could be attrition of industries or changes in industrial processes in the watershed.

Table 715-02 (2). **Areas exceeding aquatic life water quality criteria in Narragansett Bay. (Data are from Wright *et al.*, 1992a; Kipp and Zingarelli, 1991; and Metcalf & Eddy, Inc., 1991a.)**

Substances	Areas Exceeding Water Quality Criteria for the Protection of Aquatic Life
PCBs	Blackstone River (MA) downstream of Upper Blackstone WWTF Blackstone River (RI) downstream of Woonsocket WWTF to tidal portion of the river Mouths of Pawtuxet, Moshassuck, and Ten Mile rivers
Cadmium	Pawtuxet River near Warwick and Cranston WWTFs Mouths of Blackstone, Pawtuxet, Ten Mile, and Woonasquatucket rivers Blackstone River (MA/RI) between Upper Blackstone and Woonsocket WWTFs
Copper	Blackstone River (MA) downstream of Upper Blackstone WWTF Blackstone River (RI) near Woonsocket WWTF Pawtuxet River below Cranston WWTF Mouths of Blackstone, Moshassuck, Pawtuxet, Ten Mile, and Woonasquatucket rivers Seekonk and Providence rivers
Chromium	Mouths of Blackstone, Moshassuck, and Ten Mile rivers
Nickel	Seekonk and Providence rivers
Lead	Blackstone River (MA) downstream of Upper Blackstone WWTF Blackstone River (RI) downstream of Woonsocket WWTF Pawtuxet River near Warwick and Cranston WWTFs Mouths of Blackstone, Moshassuck, Pawtuxet, Ten Mile, and Woonasquatucket rivers

A study of the effectiveness of three industrial pretreatment programs uncovered significant areas that need improvement (Sutinen and Lee, 1990). The study showed that permit requirements for pretreatment are not always met and that the UBWPAD WWTF in Worcester, Massachusetts, has increased its metals loadings to the Bay. Another study has indicated that metals loadings from the Fall River, Massachusetts, WWTF have also increased (Metcalf & Eddy, Inc., 1991a).

02-03-07 Pollutant Concentrations in Natural Resources

The presence of toxic pollutants in Narragansett Bay waters and sediments can impair the growth, reproduction, and general health of marine animals and plants. High concentrations of contaminants in marine fish and shellfish that are consumed by the public can cause human health effects. Shellfish such as mussels and quahogs concentrate pollutants above the levels found in their surroundings. Concentrations of contaminants in shellfish vary depending upon location of the animals within the Bay and their ability to metabolize individual pollutants.

In general, concentrations of toxic metal and toxic organic contaminants in shellfish are higher in the Providence River than in the middle or lower parts of the Bay (Metcalf & Eddy, Inc., 1991a). However, there are pock-

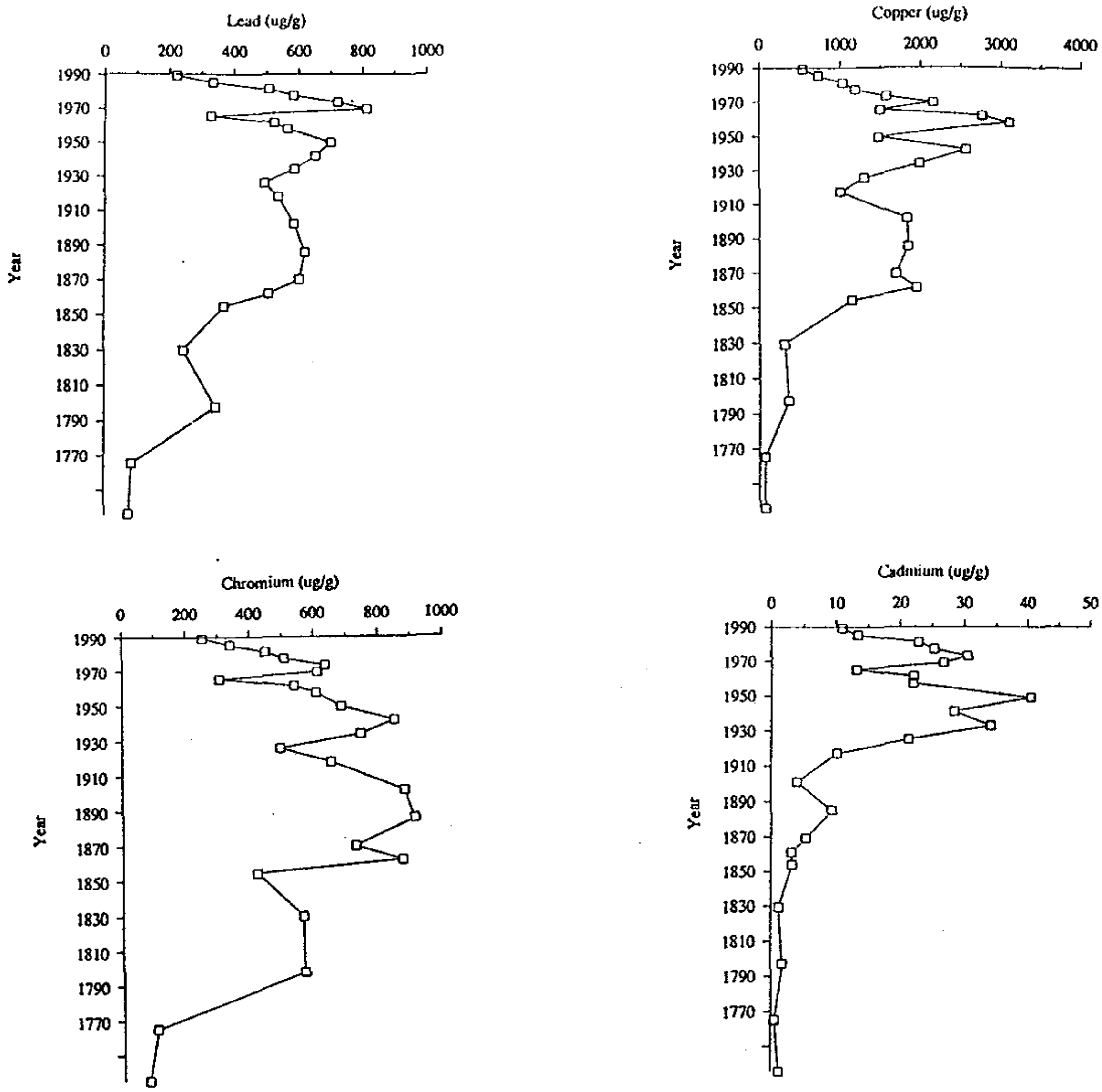


Figure 715-02 (14). Concentrations (micrograms metals/gram of sediment) of metals in sediment cores from the Seekonk River. (Data are from Corbin, 1989.)

ets of increased levels of toxic metals in areas thought to receive only local inputs of pollutants. For example, there are elevated concentrations of metals in shellfish from the area near the Naval Air Rework Facility at Quonset Point, an area that also has high concentrations of toxic metals and organic compounds in the sediments.

Concentrations of toxic organic compounds in shellfish trend from higher in the Upper Bay to low in the Lower Bay, although localized high concentrations of PHCs and PAHs have been found in shellfish from Allen Harbor, which is just north of Davisville and Quonset Point and near the site of an abandoned Navy landfill.

No historical trends in concentrations of contaminants in shellfish have been found. Concentrations of metals in quahogs have varied by a factor of less than two since 1971. This lack of a trend suggests that either exposure concentrations have remained relatively constant or that quahogs can metabolically control internal metal concentrations.

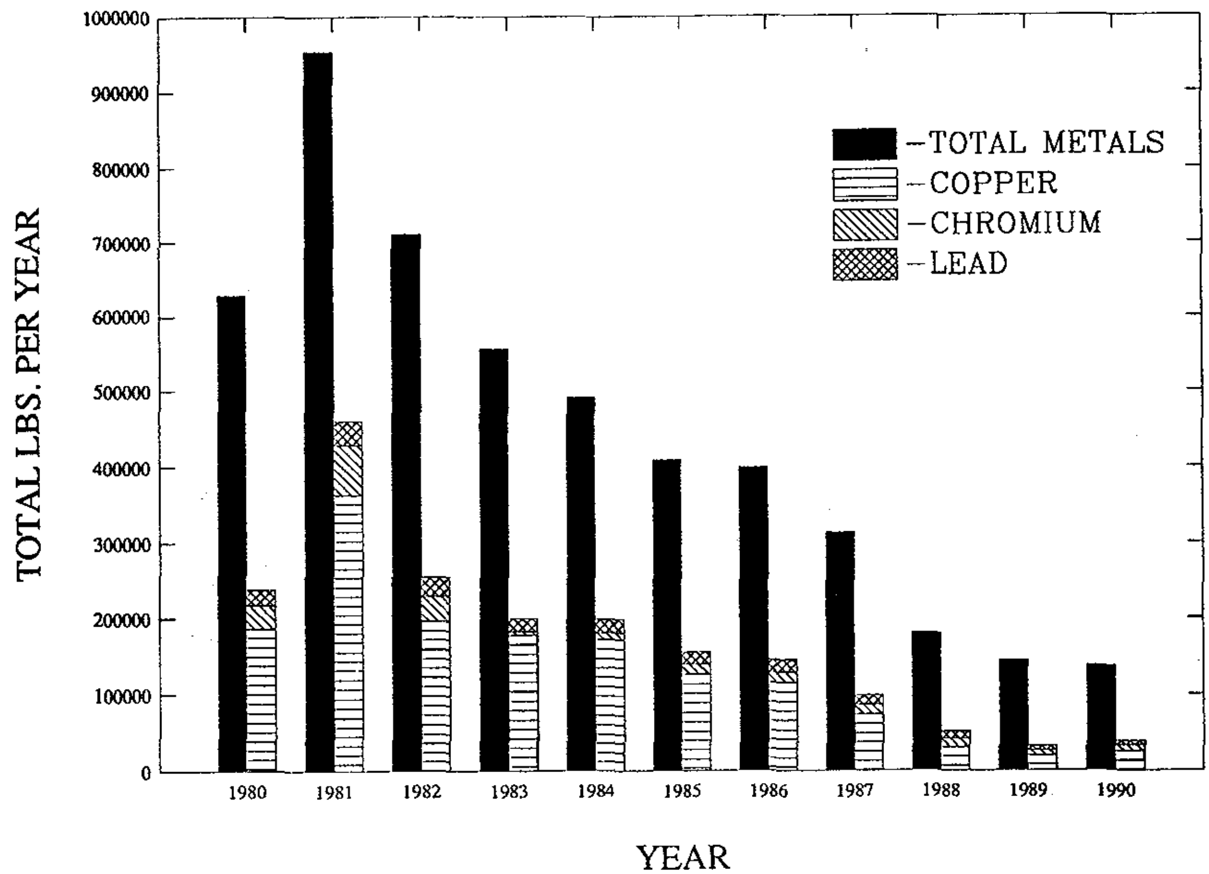


Figure 715-02 (15). Annual inputs of metals from the Field's Point WWTF. (Data are from the Narragansett Bay Commission, 1990.)

02-03-08 Comparisons to Other Estuaries

The National Status and Trends Program, conducted by NOAA, surveys more than 200 sites on the East, West, and Gulf coasts of the United States and Hawaii for concentrations of metals and organic contaminants in sediments and animals (Table 715-02(3)) (NOAA, 1989a, 1989b). Status and Trends Program data from 1984 to 1987 show that Narragansett Bay sediments are similar to other northeast, urban estuaries. For mercury, selenium, silver, and PAHs, sediments from Narragansett Bay rank among the 20-most-contaminated embayments measured by NOAA (NOAA, 1989a, 1989b).

Mussels collected in Narragansett Bay have ranked among the 20-most-contaminated of the National Status and Trends Program sites for copper and lead. In 1986, Narragansett Bay mussels were sixth-most-contaminated out of 72 for copper, eighth of 145 for lead, and twenty-fifth of 145 for nickel. Concentrations of contaminants in flounder livers ranked fourteenth of 42 for PCBs and sixth of 42 for lead (NOAA, 1989a, 1989b).

Table 715-02 (3). **Average concentrations of organic contaminants (nanograms of metals/gram) and toxic metals (micrograms of metals/gram) in selected estuaries. (Data are from NOAA National Status and Trends Program, NOAA, 1989a, 1989b. Tissues are blue mussel for all sites except Delaware Bay, where oysters were sampled.)**

	PAH	PCB	Copper	Chromium	Cadmium	Lead
Sediments*						
Narragansett Bay	3,890	151	87.1	148	0.565	88.2
Boston Harbor	19,300	673	172	308	2.02	178
Salem Harbor, MA	15,600	591	126	3,370	9.79	260
Delaware Bay	980	122	26.6	111	0.810	44.0
Elliot Bay, WA	11,000	902	243	214	2.47	70.3
Bellingham Bay, WA	1,640	10.0	58.9	207	0.440	13.5
Hudson-Raritan	5,830	539	179	216	2.12	230
Tissues**						
Narragansett Bay	160	270	9.00	1.70	1.30	4.45
Boston Harbor	1,520	820	12.2	2.00	1.32	9.70
Salem Harbor, MA	580	500	11.0	4.10	0.780	22.0
Delaware Bay	234	350	298	0.682	7.70	0.718
Elliot Bay, WA	4,200	700	10.0	1.60	2.60	3.10
Bellingham Bay, WA	330	100	11.0	3.40	3.10	1.20
Hudson-Raritan	1,600	1,990	15.3	5.16	5.90	10.9

*Average of 4-year mean concentrations from 3-4 sites
**Average of 3-year mean concentrations from 2-3 sites

02-04 Living Resources and Critical Habitats

02-04-01 Phytoplankton

Tiny, single-celled plants, phytoplankton, provide most of the energy for animals that live within Narragansett Bay (Kremer and Nixon, 1978; Kremer, 1990). Because Narragansett Bay is a relatively deep estuary, seaweeds, seagrasses and salt-marsh grasses are less important as food sources, although, to the extent these habitats have survived shoreline modification, they provide critical spawning and nursery habitat (French *et al.*, 1992). Phytoplankton, including diatoms and flagellates, are food for zooplankton, small animals that live in the water column, and for some fishes. Living and decaying phytoplankton also feed many of the animals living on the bottom of Narragansett Bay, including filter-feeding shellfish.

Typically, populations of phytoplankton bloom in late winter to early spring and again in the late summer, although this pattern may vary (Figure 715-02(16)) (Hinga *et al.*, 1989). Denser populations of plankton are found in the upper portions of the Bay than at the mouth, possibly because the nutrients in sewage act as fertilizer.

Few major changes in the numbers or kinds of phytoplankton over the past 35 years have been documented (Hinga *et al.*, 1989). One major event did occur in 1985 when a very small and previously unidentified alga, *Aureococcus anophagefferens*, bloomed (Smayda, 1988, 1989). The algae were so abundant that the event became known as a "brown tide." Because the brown tide algae were a poor food source, shellfish consumed them in great quantities but were unable to grow or thrive. Many shellfish died, particularly mussels and bay scallops. The cause of this bloom remains unknown, and it is not possible to attribute its appearance directly to pollution of the Bay. Another brown tide event occurred in 1986, although this bloom was limited to some coves and embayments, including Greenwich Cove.

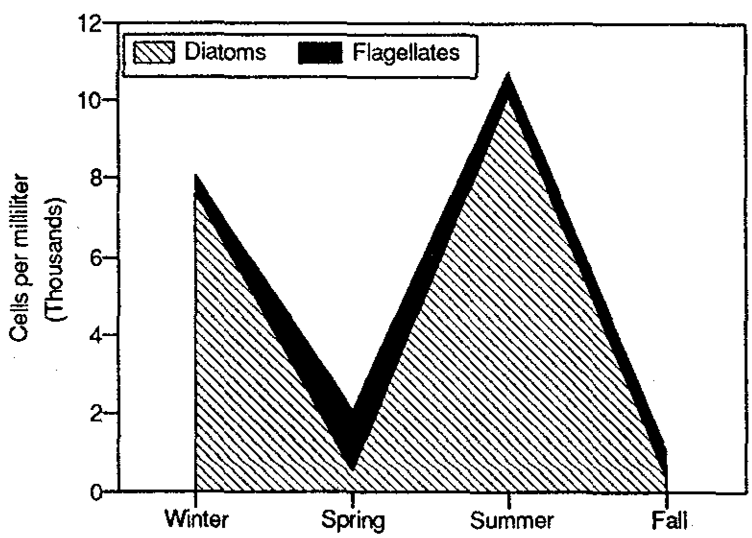


Figure 715-02 (16). Annual cycle of phytoplankton populations in Narragansett Bay. (Data are from Hinga *et al.*, 1989.)

02-04-02 Zooplankton

The zooplankton community of Narragansett Bay is similar to other open-water coastal areas in the Northeast (Durbin and Durbin, 1989, 1990). The community is dominated by two species of copepods, *Acartia hudsonica* and *Acartia tonsa*. Copepods are very small crustaceans, related to lobsters and crabs. No dramatic differences between the populations of zooplankton of the upper and lower parts of the Bay have been noted, nor do there seem to be any major historical changes in the community (Durbin and Durbin, 1989, 1990).

02-04-03 Bottom Animals

The bottom animals or benthos of Narragansett Bay have been studied since before the turn of the century (Frithsen, 1990). Because most attached or infaunal benthic animals live most of their lives in the same area, scientists think of them as good integrators of conditions at one location over long periods of time. However, changes in benthic populations along a gradient from the Upper Bay to the Lower Bay have been difficult to interpret (Frithsen, 1990). Pollutant concentrations decrease along that gradient, but salinity and loadings of organic matter also vary along the same pattern.

Among the animals living on the bottom of Narragansett Bay are several commercially important shellfish, including the hard clam (*Mercenaria mercenaria*), American lobster (*Homarus americanus*), surf clam (*Spisula solidissima*), blue mussel (*Mytilus edulis*), rock crab (*Cancer irroratus*), and Jonah crab (*Cancer borealis*) (French *et al.*, 1992). In the past, the soft-shell clam (*Mya arenaria*), bay scallop (*Argopecten irradians*), and American oyster (*Crassostrea virginica*) were also abundant in Narragansett Bay.

Of these shellfish, the hard clam or quahog fishery is the most important commercial fishery remaining in the Bay (Pratt *et al.*, 1992). Only the lobster fishery brings in more money to Rhode Island fishermen, although many lobsters are caught offshore (Figure 715-02(17)).

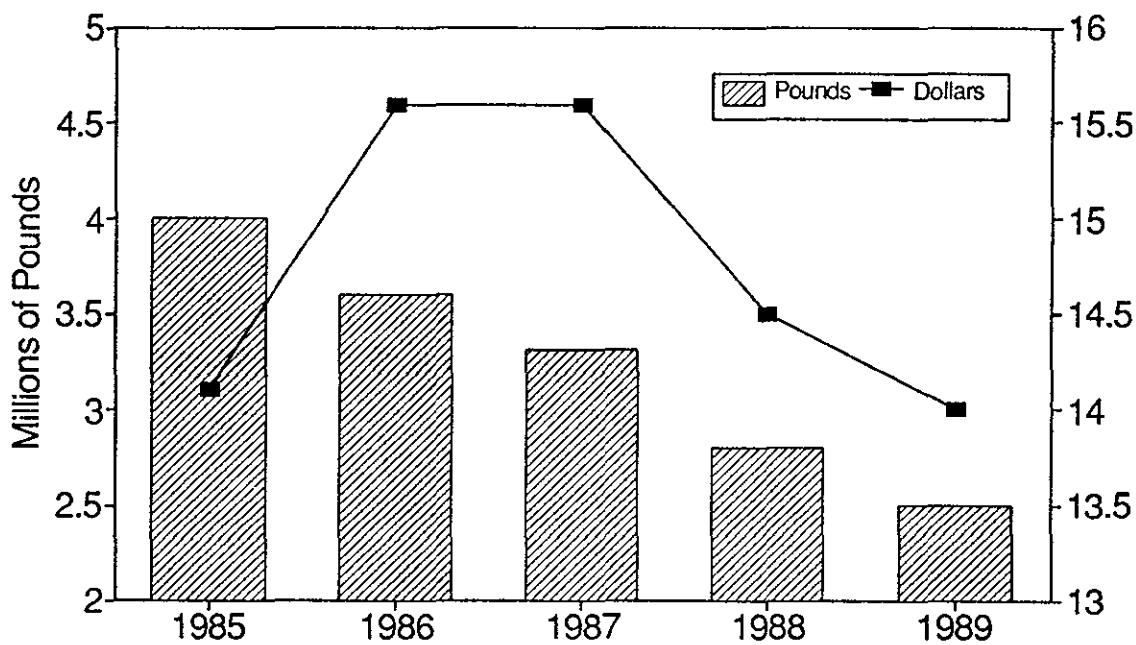


Figure 715-02(17). Commercial landings of Narragansett Bay quahogs. (Data are from NOAA/NMFS.)

The quahog is the most abundant animal of its size living within the bottom sediments of Narragansett Bay (Frithsen, 1990; Pratt *et al.*, 1992). The highest densities of quahogs are found in the mid and upper portions of the Bay, including the Providence River, an area that is currently closed to harvesting. Quahogs in the Providence River have the highest measured tissue levels of toxic contaminants in the Bay basin, although there is no histopathological evidence of disease related to pollutant exposure (Kern, 1990).

02-04-04 Fishes

Both bottom-dwelling and open-water fish inhabit or visit Narragansett Bay (Jeffries and Johnson, 1974; Powell 1989). Among the bottom fish, the most common commercial species used to be the winter flounder, *Pseudopleuronectes americanus* (Figure 715-02(18)) (Jeffries *et al.*, 1989). Winter flounder live year-round within the Bay and may migrate outside the Bay to Rhode Island Sound (Gray, 1991). Periodically, abundances of winter flounder have declined drastically. For example, from 1968-1976, the population declined to only 15 percent of its 1968 levels (Jeffries *et al.*, 1989). By 1979, the population had recovered, but it subsequently declined again. Although these cycles are not completely understood, they appear to be closely related to higher-than-average water temperatures during the development and growth stages of young fish (Jeffries and Johnson, 1974). Such population fluctuations may be quite normal. However, chronic overfishing and alteration of spawning habitat are now thought to be the primary cause for the declining winter flounder population (Figure 715-02(19)). Although pollution has not been directly implicated as a cause for winter flounder declines, the Narragansett Bay Project has found that abnormalities in flounder livers are more prevalent in the Upper Bay at Warwick Neck, than in the Lower Bay at Whale Rock (Lee *et al.*, 1991).

Other fishes, such as scup, menhaden, striped bass and bluefish, make seasonal migrations into Bay waters. Recreational fisheries exist for striped bass and bluefish. The commercial menhaden fishery is the largest in the Bay by weight.

02-04-05 Birds

Resident and migratory birds are common within the Narragansett Bay region (French *et al.*, 1992). Gulls and terns nest on islands and other isolated areas. The Bay is an important wintering area for many sea ducks and other waterbirds. Small shorebirds pass through the Narragansett Bay area as they migrate north in the spring and south in the fall. Raptors, such as osprey, historically nested along the coast in large numbers. Their populations were diminished by DDT and other pesticides and by habitat loss, but are currently rebounding. Sites on Sakonnet Point, Fort Wetherill, Prudence Island, Rose Island, Big Gould Island, Dyer Island, Hope Island, Little Gould Island, Hog Island and Spar Island are some of the important locations of colonial waterbird rookeries in the Bay (French *et al.*, 1992).

02-04-06 Habitats

Ecologically fragile habitats in the Narragansett Bay system include saltwater and freshwater wetlands, fish breeding and nursery grounds, inland surface waters, and shallow embayments that can be easily affected by excess nutrients, toxic compounds, solids (erosion), and outright destruction or modification.

Salt marshes provide a nursery ground for fish and shellfish, protection from coastal storms, and habitat for wildlife. Salt marshes cover about 2800 acres of land around Narragansett Bay. An additional 4400 acres are tidal flats. Within Narragansett Bay, there are approximately 80 km of narrow, fringing salt marsh, marshes that line the edges of rocky shores or developed areas (French *et al.*, 1992).

Freshwater wetlands provide habitats for plants and animals, filters for pollutants entering the groundwater, and protection from stormwater damage. Freshwater wetlands make up about 63,000 acres, six percent of the watershed.

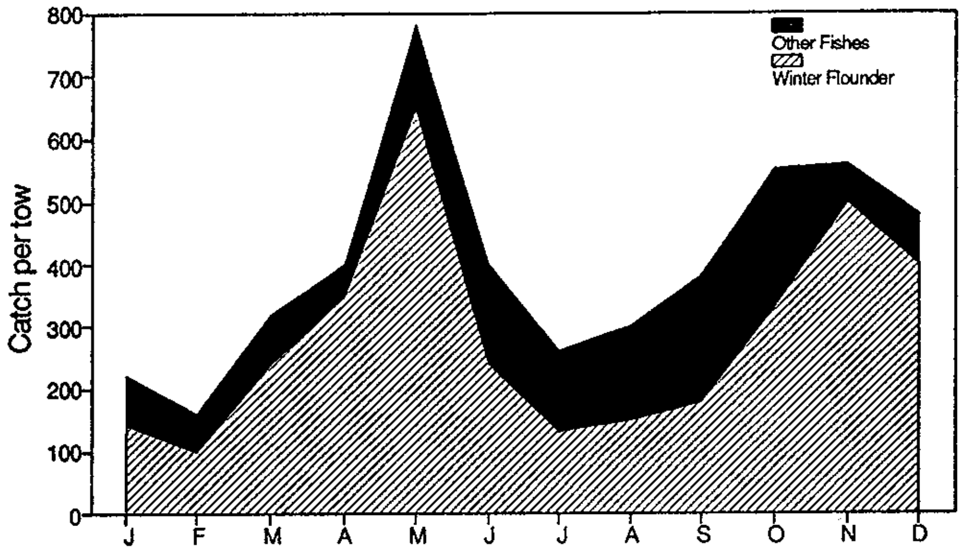


Figure 715-02 (18). **Annual fluctuations in fish populations in Narragansett Bay. (Data are from Jeffries *et al.*, 1989, and represent surveys rather than commercial harvests.)**

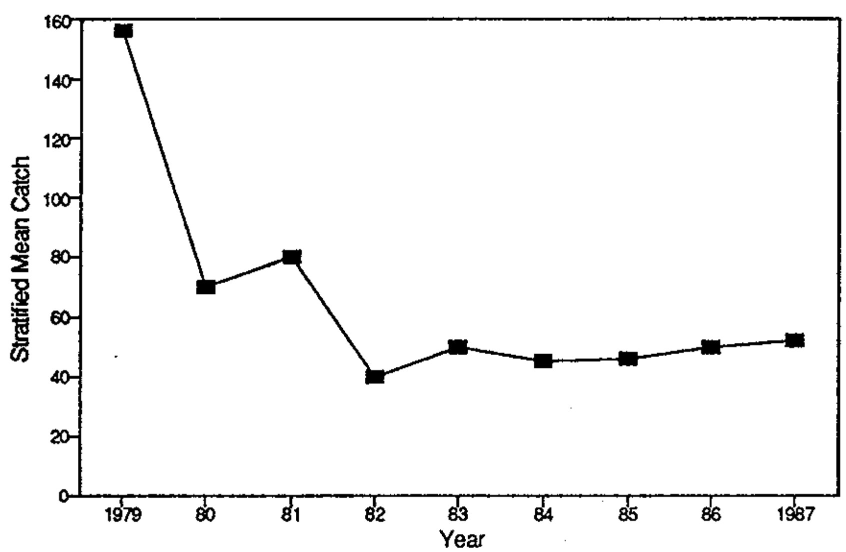


Figure 715-02 (19). **Winter flounder catches between 1979 and 1987. (Data are from NOAA/NMFS and reflect surveys rather than commercial harvests.)**

Fish habitats in Narragansett Bay include areas for anadromous fish runs; spawning and nursery areas for winter flounder, juvenile lobsters, and other fish and shellfish; and current and historic shellfish beds. Most winter flounder larvae are found in the Upper Bay (French *et al.*, 1992). One part of the National Estuarine Research Reserve, just offshore from Nag Creek Marsh, is thought to be a spawning site for flounder.

Nutrient-sensitive areas include embayments, salt ponds, freshwater ponds, bogs, and fens. These poorly flushed areas are particularly sensitive to development and commercial and recreational activities. These areas are not well-studied but are the areas that may be most affected by excess loadings of nutrients (Penniman *et al.*, 1991b).

02-05 Public Health Concerns

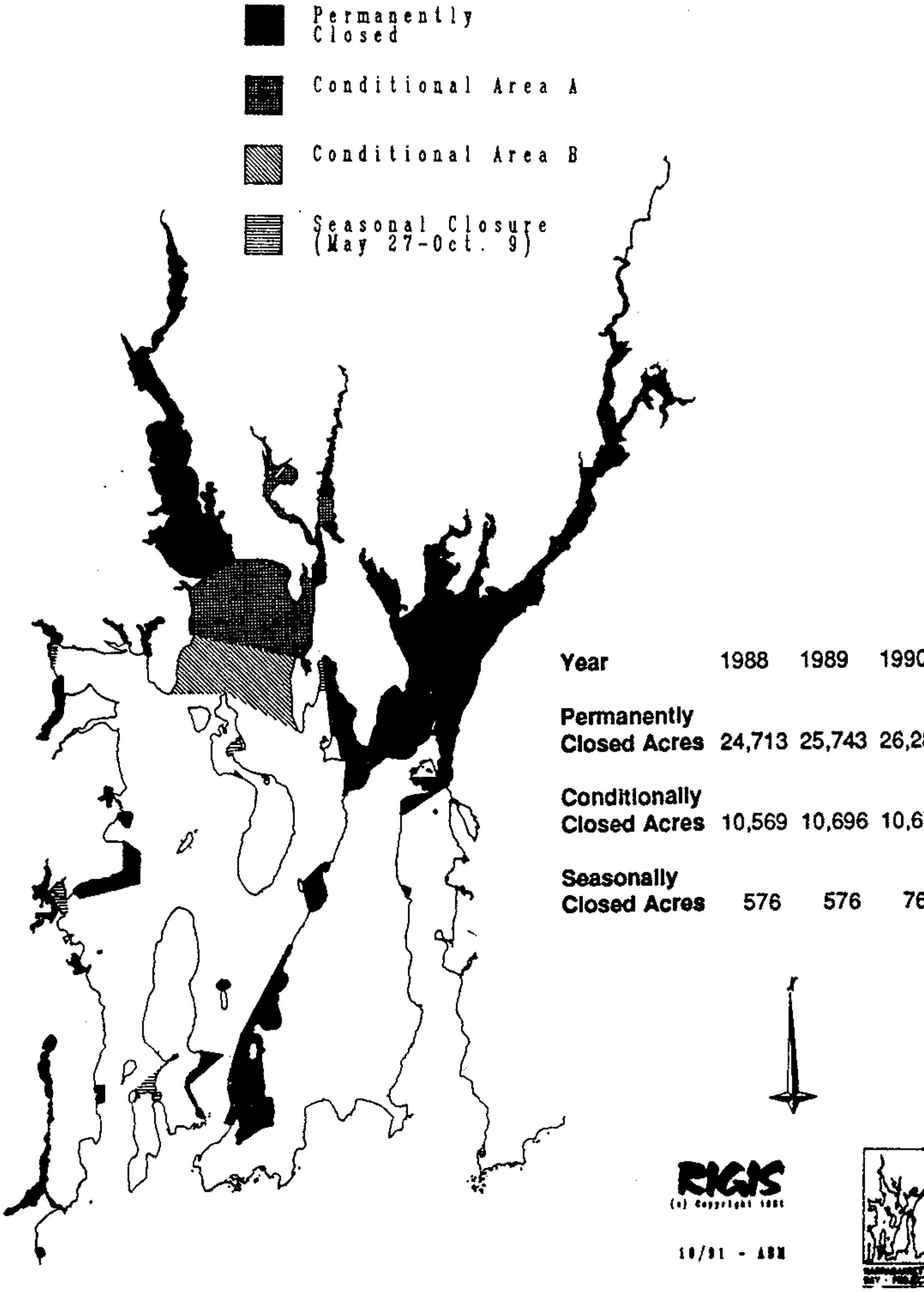
The major public health concern for Narragansett Bay, as for other coastal areas in the United States, is the safety of eating raw or incompletely cooked shellfish (quahogs, oysters) harvested from sewage-contaminated waters (Kipp, 1990). However, another public health concern exists with respect to the additive lifetime risk of contracting cancer for people who consume large amounts of seafood harvested from chemically contaminated areas of the Bay. A more minor public health concern for the region is the risk of infection from swimming in sewage-contaminated waters.

In the past, consumption of sewage-contaminated seafood led to outbreaks of bacterial and viral diseases, such as typhoid fever cholera, and hepatitis. Fortunately, such outbreaks have not occurred in the Narragansett Bay area for decades. Wastewater is now disinfected with chlorine to kill bacteria, and bacterial indicators of fecal contamination are routinely monitored in shellfish harvesting waters. Today, there is greater concern about sewage-derived viruses, such as those that cause infectious hepatitis and gastroenteritis since chlorine is a relatively ineffective viricide compared to alternative disinfection techniques.

Shellfish beds in Narragansett Bay are closed if the levels of fecal coliform bacteria indicate that sewage has contaminated the clams. Approximately 40 percent of the Bay is restricted to shellfishing. Twenty-eight percent of the Bay, including Mount Hope Bay, the Providence River, and several smaller areas are permanently closed, because the levels of fecal coliform bacteria are consistently higher than the state standard. Upper Narragansett Bay is a "conditional" area that is closed for at least seven days following a half inch of rain over a one-day period. These closures are made because of the great influx of untreated sewage from CSOs during rain. An additional 769 acres near marinas are closed during the summer months, because they can receive sewage discharges from boats. In 1991 an additional 40 acres in the Palmer River were closed, due to high levels of fecal coliform bacteria that have been attributed to septic systems and stormdrains as sources (Figure 715-02(20)) (Karp *et al.*, 1990).

The long-term cancer risk from eating fish and shellfish from Narragansett Bay is probably not currently a problem for most consumers, although concern for eating seafood harvested from urban estuaries remains a public health issue for all urban coastal areas (Kipp, 1990).

Narragansett Bay quahogs do not exceed U.S. Food and Drug Administration (FDA) alert limits for mercury, PCBs, chlordane, DDT, or DDT's breakdown products, DDE or DDD, the only contaminants for which such limits have been set. Using estimates of average and maximum consumption, the Narragansett Bay Project found that heavy consumers (15 g/day) of quahogs from the Providence River could be at a slightly greater risk of contracting cancer compared to average consumers (1.2 g/day) (Kipp, 1990). In comparison to other estuaries, consuming quahogs from Narragansett Bay is safer than eating fish from New York Harbor or Lake Michigan or clams, lobster or flounder from Quincy Bay in Massachusetts.



Year	1988	1989	1990	1991
Permanently Closed Acres	24,713	25,743	26,289	26,329
Conditionally Closed Acres	10,569	10,696	10,672	10,672
Seasonally Closed Acres	576	576	769	769

Figure 715-02(20). Shellfish closure areas in Narragansett Bay. (Data from NBP, RIGIS.)

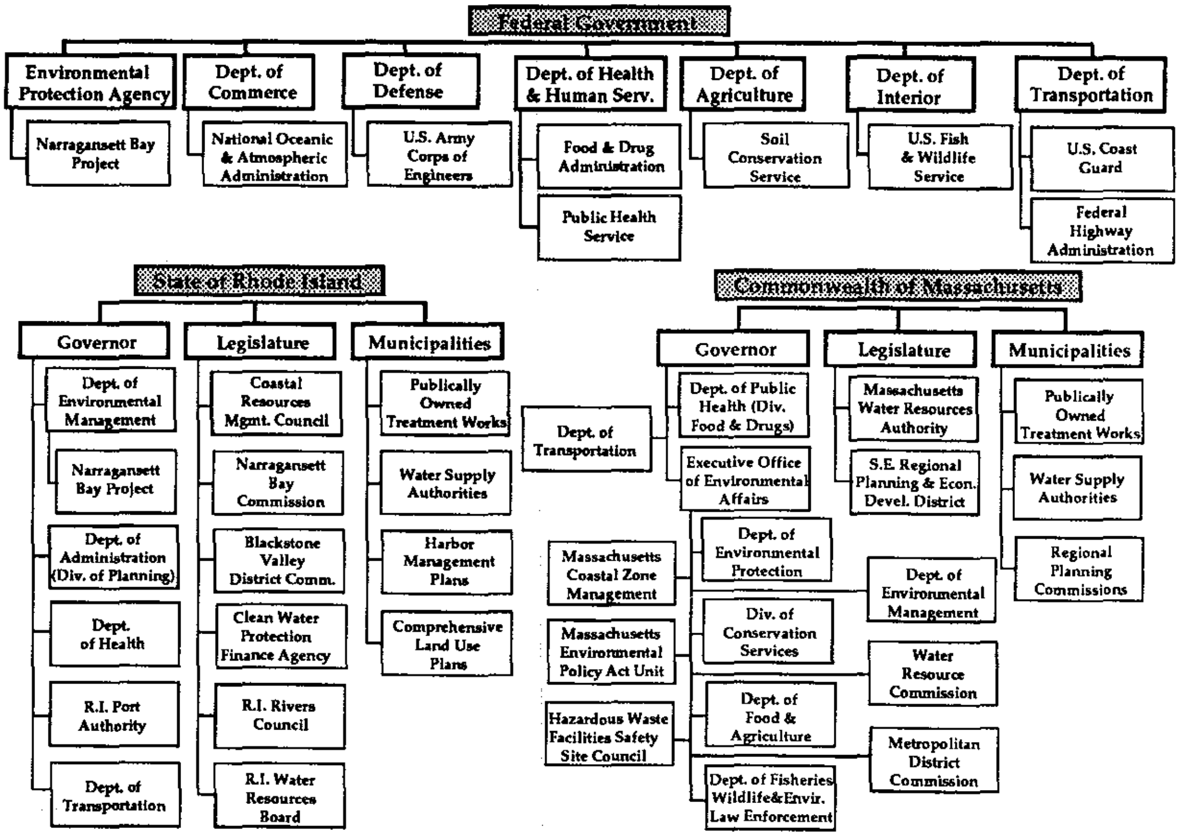


Figure 715-02 (21). Federal, state, and local agencies involved in Narragansett Bay planning and regulation.

For winter flounder, the pattern is similar to that for quahogs. Consumers of average amounts for flounder (1 g/day) are at no increased risk, while persons who consume large amounts of flounder (165 g/day) would be at slightly above what EPA believes is an acceptable risk (Kipp, 1990). Few data are available to calculate health risks of consuming other fish or shellfish from Narragansett Bay. However, the Rhode Island Department of Health (RIDOH) has issued a health advisory regarding consumption of bluefish and striped bass because of PCB levels. Since these species migrate along the entire East coast, their contamination is an issue for the entire region.

02-06 Bay and Watershed Governance

Resource management and pollution control in Narragansett Bay are governed by a complex network of federal, state and local authorities (Figure 715-02(21)). The State of Rhode Island takes the primary state-level role in governance of the Bay's open water. However, since 61 percent of the Narragansett Bay watershed is within Massachusetts, its environmental laws and policies also affect the Bay.

Congress's passage of the Clean Water Act (CWA) of 1972 firmly established the federal commitment to controlling pollution in coastal waters, and this legislation has controlled subsequent efforts by federal, state, and local agencies. EPA has the primary responsibility for the National Estuary Program, established by Congress in the amendments to the CWA in 1987.

Congress also enacted the Coastal Zone Management Act (CZMA) in 1972 to preserve, protect, develop and enhance coastal resources. Activities conducted under this act are administered by NOAA and state Coastal Zone Management (CZM) programs. The CZMA was amended in 1990 to include much broader state responsibility for controlling nonpoint source pollution in the coastal zone.

Other federal laws that affect Narragansett Bay include the following:

- National Environmental Policy Act of 1965, which requires that any project involving federal legislation, funds, or activities that could significantly alter the quality of the human environment must be the subject of an environmental impact statement.

- Coastal Barrier Resource Act of 1982, which protects barrier beaches, wetlands, and nearshore waters and provides funds for maintenance, research, and public safety.

- Estuarine Areas Act of 1968, which provides for the preservation, protection, and restoration of valuable estuaries.

- Shoreline Protection Act of 1988, which protects coastal waters from litter and pollution by providing for permits to transport municipal and commercial wastes in coastal waters and regulates waste handling.

- Marine Protection, Research and Sanctuaries Act of 1972, which regulates ocean dumping of industrial and municipal wastes and dredged material.

- Submerged Lands Act of 1953, which allows states to manage, administer, lease, develop, and use submerged land and natural resources beneath navigable waters.

- Land and Water Conservation Fund Act of 1965, which provides funds for and authorizes federal assistance to states in planning, acquisition, and development of needed land and other areas and facilities.

- River and Harbors and Flood Control Act of 1970, which requires that all civil projects undertaken by the Army Corps of Engineers consider environmental, social, and economic effects.

- National Flood Insurance Act of 1968, which encourages state and local governments to make appropriate land-use adjustments to constrict the development of land that is exposed to flooding.

- Endangered Species Act of 1973, which identifies, lists, and protects endangered and threatened species and requires that all federal actions avoid destroying or modifying critical habitats.

- Fish and Wildlife Coordination Act of 1958, which requires that fish and wildlife conservation receive equal consideration and be coordinated with other features of water resources programs through planning, development, maintenance, and coordination of fish and wildlife conservation and rehabilitation.

- Fish and Wildlife Conservation Act of 1980, which provides funds and technical assistance to states for the development, revision, implementation, and monitoring of conservation plans and programs for nongame fish and wildlife.

- Migratory Bird Conservation Act of 1962, which provides funds and authorization for the acquisition of areas for the protection and management of migratory birds.

- Wild and Scenic Rivers Act of 1968, which provides for preservation of selected rivers.

- Magnuson Fishery Conservation and Management Act of 1976, which promotes domestic commercial and recreational fishing through sound conservation and management principles.

- Anadromous Fish Conservation Act of 1965, which provides for the conservation, development, and enhancement of fishes that spawn in freshwater and live as adults in saltwater.

- Department of Transportation Act of 1966, which establishes a policy that special efforts should be made to preserve the natural beauty of the countryside and public park and recreation lands, wildlife and waterfowl refuges, and historic sites.

- Water Bank Act of 1970, which implements a continuous program to prevent the serious loss of wetlands and preserves, restores, and improves wetlands.

- Safe Drinking Water Act, as amended in 1986, which authorizes the adoption of national standards and treatment technologies for public drinking water.

- Resource Conservation and Recovery Act, the 1976 amendment to the Solid Waste Disposal Act, which provides standards for treatment, storage, and disposal facilities for hazardous wastes, aimed at preventing contamination of surface and groundwater.

- Comprehensive Environmental Response, Compensation, and Liability Act of 1980, which established the Superfund program to clean up existing or closed hazardous waste sites.

Federal agencies that influence pollution control and resource management issues include not only EPA and NOAA, but also FDA, which sets allowable levels of contaminants in fish and shellfish consumed by humans; USACOE, which regulates dredging activities and runs the permit program which governs the discharge of dredged and fill material into navigable waters; the U.S. Coast Guard, which is responsible for enforcing vessel discharge prohibitions and responding to spills in navigable waters; the U.S. Navy which possesses numerous properties in coastal areas; the Federal Energy Regulatory Commission (FERC), which licenses hydroelectric facilities; and the U.S. Fish and Wildlife Service (USFWS) which is charged with managing and protecting indigenous fish and wildlife.

The State of Rhode Island enacted legislation as early as 1920 to "prohibit and regulate the pollution of waters of the state." RIDEM, formed in 1977, now has jurisdiction over water quality policy and management. RIDEM has also produced the *Non-Point Source Management Plan* and the *State Clean Water Strategy*. The *Non-Point Source Management Plan* specifies management approaches to decrease nonpoint sources of contaminants to the Bay. The *State Clean Water Strategy* will integrate assessment and management plans for point and nonpoint sources of contaminants.

Another Rhode Island state agency, CRMC, was established in 1971 as an independent planning and management authority. CRMC is charged with protecting and managing Rhode Island's coastal zone, and has the authority to develop and enforce plans related to the use of land and water in coastal areas. The CRMC, in collaboration with RIDEM and other nonpoint source planning programs, is expected to develop the State's Coastal Nonpoint Pollution Control Program (CNPCP) mandated under Section 6217 of the 1990 Amendments to the federal CZMA.

Other programs administered by the state include the following:

- ISDS permit process, which ensures that the siting, design, and operation of septic systems is protective of public health and environmental quality.

- Freshwater wetlands permit process, which protects water quality, groundwater recharge abilities, wildlife habitat, recreational values, and unique wetland characteristics.

- Water quality classification process, which classifies Rhode Island waters and sets forth policies for their use.

- Natural Heritage Program, which identifies habitats for rare or threatened species.

- Endangered Species of Plants and Animals Act, a state law that prohibits the sale of federal endangered or threatened species.

- Erosion and Sediment Control Act, which enables communities to require developers to submit erosion and sediment control plans.

- Groundwater Protection Act, which establishes state policies for groundwater protection.

- Wellhead Protection Program, which delineates wellhead areas in need of protection, identifies contaminant sources, develops management strategies and ordinances, guides siting of new wells, and provides contingency plans for events of well contamination.

- Underground Storage Tank Regulation, which implements a registration system and establishes design requirements, testing schedules and procedures, and measures for siting underground tanks.

- Hazardous Waste Regulation, which governs the storage, transport, treatment, and disposal of hazardous wastes.

- Hazardous Waste Management Facilities, which establishes a process for siting hazardous waste management facilities.

- Solid Waste Regulation, which authorizes prohibition of disposal of solid waste in groundwater aquifer areas.

- Underground Injection Control Program, which is intended to preserve the quality of the groundwaters of the state by assuring the proper location, design, construction, maintenance, and operation of injection wells and other subsurface disposal systems.

- Pesticide Control, which authorizes regulation of registration, sale, storage, transport, use, application, and disposal of pesticides.

- Public Drinking Water Protection Act, which allows public water supply authorities to impose a charge on water use.

One recent Rhode Island law affects land-use issues in the watershed and consequently will affect the water quality of the Bay. The Comprehensive Planning and Land Use Regulation Act, passed in 1988, requires all cities and towns to produce a comprehensive plan to guide development. The Zoning Enabling Act, enacted in 1991, expands local authority to enforce the plans developed under the Comprehensive Planning and Land Use Regulation Act.

The Commonwealth of Massachusetts has agencies and programs that mirror many of the activities carried out in Rhode Island. However, proposed projects affecting Narragansett Bay may meet different financial or political priorities in Rhode Island and Massachusetts. Many local zoning ordinances also address environmental protection and resource management.

Because environmental regulation often produces conflicts between public and private rights and expectations, the federal and state courts also play an important role in governance of the Bay. Also, although they have no official regulatory capacity, environmental groups, trade organizations, other special interest groups and the local universities also influence resource management and pollution control policies.

Each of these groups—federal, state and local governments, environmental groups, marine trade organizations, other special interest groups and the universities—have the best intentions for proper management and preservation of the Bay's resources. However, the number of organizations and laws that affect the Bay is complex. It is difficult to coordinate all interested parties and applicable laws and programs.

02-07 Priorities

Narragansett Bay is a complex natural system that supports varied and sometimes conflicting human uses. However, the Bay ecosystem faces multiple environmental threats as a direct result of the intensity of human activity in the basin. These threats include, loss of overexploited fisheries, loss and degradation of critical natural habitats, and contamination of water, sediments, and living resources. In addition, unmanaged development and population growth, in combination with current waste disposal practices, have resulted in significant limitations on water quality-dependent uses of the Bay. Part 715-04 (Issues, Objectives, and Strategies) describes these problems in detail and recommends detailed policies and corrective actions to address them over the next five to ten years.

Three relatively distinct regions of the Bay and Bay watershed can be identified with respect to anthropogenic impacts and the need for restoration and protection. The first region, comprises the Providence River basin, Upper Narragansett Bay, and much of Mount Hope Bay. As described earlier, this area has the longest history and greatest magnitude of environmental insult of the entire Narragansett Bay basin which is related entirely to the history of urban and industrial development. For example, the Providence, Seekonk, Pawtuxet Rivers, and portions of the lower Taunton River have all experienced significant periods of low dissolved oxygen indicative of excessive BOD or nutrient loadings. This area also has elevated levels of various toxic pollutants in the water column, in some cases, which exceed federal and state aquatic life criteria. The long history of anthropogenic loadings of toxic compounds is apparent in the amounts of toxic materials remaining in the bottom sediments in this area. The Blackstone and Seekonk river sediments are particularly contaminated. For the Providence-Seekonk River and part of Mount Hope Bay, in particular, the volume of untreated wastewater released during rain events from CSOs carries with it huge amounts of fecal coliform bacteria and, potentially, human pathogens.

Point sources, *i.e.*, WWTFs, WWTF bypasses, CSOs, and storm drains are the major sources of pollution to this part of the Bay. In part because of this fact, control of several of these pollutants has progressed substantially. For example, BOD loadings from WWTFs have been dramatically reduced because of the mandatory secondary treatment requirements imposed pursuant to the CWA. Toxic pollutants entering the Bay have also declined dramatically, partially as a result of the CWA Industrial Pretreatment Program, part, as a result of changes in demographics, and part as a result of voluntary source reduction efforts by industry. However, as described above, water quality problems still remain. Thus, the environmental priorities are to:

- Continue to reduce the amounts of toxic pollutants entering this part of the Bay by enhancing and expanding the Industrial Pretreatment Programs, and, reducing the contributions from commercial and domestic sources.

- Determine if excessive nutrients, primarily from WWTFs, are the cause of eutrophic conditions in the Providence-Seekonk River and, if so, reduce loads of these pollutants.

- Abate the release from CSOs and WWTF bypasses of untreated wastewater that results in substantial contributions of fecal coliforms, suspended solids, and floatable wastes to this region.

The second region of the basin comprises areas that are experiencing rapid development or are already heavily developed but lack municipal sewers. For example, several sections of Narragansett Bay, such as Greenwich Bay, the Narrow River, and Wickford Harbor are increasingly being degraded by fecal wastes, nutrients, and toxic pollutants resulting in increasing limitations on water-quality dependent uses. Runoff and leachate from old, poorly designed and/or poorly maintained septic systems are believed to represent a significant pollution problem. In addition, the conversion of undeveloped land to impervious surfaces associated with development results in loss and degradation of natural habitats and greater volumes of stormwater runoff and stormwater runoff-borne pollutants. In some of the coves in this region, large numbers of boats may cause seasonal and local water quality degradation related to boater discharges of fecal wastes, fueling operations, and other boatyard-related activities. In contrast to the Upper Bay, most of the pollutants in this region derive from nonpoint sources. Therefore, solutions to these problems are somewhat more complex and, to a great extent, involve planning efforts to better accommodate growth in this region in a more sustainable manner. These solutions include:

- Regulatory and technological mechanisms to reduce loadings of on-site sewage disposal system or OSDS-derived pollutants, to surface and ground waters. These measures include better regulation of septic systems, better maintenance schemes for septic systems (*i.e.*, through the establishment of wastewater management districts), and measures to address the cumulative effects of septic systems by considering and regulating OSDS density at a subwatershed level.

- Installing marina pump-outs to reduce boater discharges of fecal waste.

- Providing municipal officials with practical technical guidance on BMPs to control nonpoint source pollution, and innovative land use and growth management practices.

The third region of the basin is represented by those areas that are currently the most pristine or the least impacted by anthropogenic activities. These areas include parts of the Sakonnet River, many of the islands in Bay, and much of the lower Bay. Many of the problems described for the mid-Bay region are only just beginning to emerge in this third region. Thus, early and aggressive application of many of the initiatives outlined above will protect these more pristine areas from significant degradation or loss of natural resources. Efforts in this region should focus on land use and growth management initiatives to prevent the irreversible loss or degradation of critical natural resources and habitats.

Finally, a Bay-wide problem is the loss, and occasionally catastrophic declines, of living resources and habitats. The solutions to these problems are the development and implementation of scientifically-based management plans, not only for commercially or recreationally important species, but also for the ecologically important species and the significant habitats on which all these organisms depend. In addition, these solutions may require the modification of the concept of "free and common fisheries" in order to control the overexploitation of many living marine resources.

In summary, managers must not be deceived into thinking that Narragansett Bay's environmental, public health, and use-related problems can be solved by focusing on a single pollutant source, class of pollutants or remedial action. Although, in many cases, control of a single source will help to reduce inputs of several contaminant types, in others, multiple sources will have to be controlled to achieve significant reductions in a single class of pollutants. The major challenges for Narragansett Bay's managers will be to evaluate the relative environmental and social importance of these problems and balance these concerns against the technological, institutional, and economic feasibility of implementing solutions.